THE RADIAL VELOCITIES OF THE MORE DISTANT STARS

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As a result of the work of Kapteyn, Campbell, and Boss it has been recognized for some years that the linear motions of the brighter stars vary with their spectral types, the velocities of the solar type stars being higher than those of types B and A. It is equally well-known, however, that the solar type stars in general have larger proper motions and so are much nearer to the sun than those of earlier types. Hence the stars, for which the velocities have been compared, have quite different distances, and if, as was once suggested by Eddington,[1] the nearer stars move more rapidly than the distant ones this fact would account, in part at least, for the apparent variation of velocity with spectral type.

In the course of an analysis of the radial velocity results from the Lick Observatory and Mount Wilson, J. C. Kapteyn derived the relationship between radial velocity and proper motion for the K type stars,[2] and found that the velocity increased rapidly with the amount of proper motion. In this computation the effect of stream motion was eliminated to a large extent by a selection of stars nearly 90° from the vertices of the streams. The Mount Wilson observations of the spectra of stars having both small and large proper motions provide the material for a similar comparison for other types of spectra. This is given in Table I: the effect of stream motion, however, has not been eliminated. The average velocity v' is corrected for a solar motion of 20 km. directed toward the apex

$$\alpha = 17 \text{ h } 59 \text{ m.} \quad \delta = +30^\circ.8$$

and no velocities exceeding 100 km. are included.

TABLE I

SPECTRAL TYPE	NUMBER OF STARS	μ	v'	NUMBER OF STARS	μ	v'
B..........	61	0″.016	8.2	52	0″.041	9.6
A...........	55	0 .019	10.0	104	0 .067	10.7
F............	20	0 .011	10.1	45	0 .530	24.6
G...........	63	0 .013	10.6	69	0 .670	24.9
M..........	27	0 .015	12.6	12	0 .170	17.6

To these we may add Kapteyn's value for the K stars with stream motion eliminated:

K..........	27	0.013	10.9	19	>0.30	26.7

It is clear from these results that the radial velocity increases rapidly with proper motion. Only a few A type stars of very large proper motion are known. Of those observed at Mount Wilson for which μ exceeds $0''.20$, two have velocities of over 150 km.; one has a velocity of 87 km.; and the average for the other six is 20 km.

In view of this relationship between proper motion and radial velocity it becomes of especial interest to compare the Mount Wilson observations of stars of small proper motion with the results of W. W. Campbell for stars selected on the basis of apparent magnitude alone. Table II contains the average values of the radial velocities corrected for solar motion, of 1034 stars published in Campbells' first table.[3] No constant K has been applied to these results. The proper motions have been taken from Boss's catalogue for the individual stars appearing in Campbell's later lists, and hence the mean values are not strictly correct for the stars whose velocities are given. Since the number of stars is large, however, it does not seem probable that these values can be seriously in error.

TABLE II

SPECTRAL TYPE	CAMPBELL				MOUNT WILSON		
	No. Stars for v'	No. Stars for μ	μ	v'	No. Stars	μ	v'
O and B	141	224	$0''.031$	8.99	61	$0''.016$	8.23
A	133	206	0 .094	9.94	55	0 .019	10.04
F	159	192	0 .234	13.90	20	0 .011	10.14
G } K }	529	549	0 .202	15.15	63	0 .013	10.60
					56	0 .014	11.53
M	72	78	0 .074	16.55	27	0 .015	12.56

The omission of 5 stars of the A type would reduce the proper motion for Campbell's stars from $0''.094$ to $0''.079$. The principal feature of this comparison is the relatively close agreement of the Lick and Mount Wilson results for the B and A stars, and the large difference for those of other types. This difference appears to be associated directly with the great increase in proper motion between the A and F type stars in Campbell's list. With the aid of the relationship already referred to between proper motion and radial velocity deduced by Kapteyn for the K stars it is possible to apply corrections to Campbell's results to reduce to the proper motion $0''.031$ of the B stars. The resulting values are shown under v' in Table III. In addition both the Lick and the Mount Wilson velocities have been corrected for the effect of stream motion by the approximate method devised by Eddington.[4]

TABLE III

SPECTRAL TYPE	CAMPBELL			MOUNT WILSON		
	v'	Corrected[1]	μ	v'	Corrected[1]	μ
O and B.....	9.0	9.0	0″.031	8.2	8.2	0″.016
A...........	8.6	6.8	0 .031	10.0	7.7	0 .019
F...........	9.0	7.8	0 .031	10.1	8.8	0 .011
G }	11.0	9.6	0 .031	10.6	9.2	0 .013
K }				11.5	10.0	0 .014
M..........	15.6	13.6	0 .031	12.6	10.9	0 .015

[1] v' corrected for stream motion.

In his later discussion of the solar motion as derived from the several spectral types Campbell has given the average radial velocities with a constant correction *K* applied to the velocity of each star. This constant has a value ranging from about zero for the F and G stars to over 4 km. for those of type B. If these results are treated in the same way as those of Table III we obtain the following values:

TABLE IV

TYPE	v'	CORRECTED	μ
O and B....................	6.5	6.5	0″.031
A..........................	9.6	7.4	0 .031
F..........................	9.5	8.3	0 .031
G..........................	9.1	7.9	0 .031
K..........................	13.2	11.5	0 .031
M..........................	16.1	14.0	0 .031

The constant *K* as used by Campbell is the average velocity v' taken according to sign for the stars of each spectral class, and is dependent upon the value of the solar motion. For all of the Mount Wilson stars the same value, $V = 20$ km., has been used. This gives the following average velocities taken according to sign:

B +1.26; A −0.24; F −0.86; G +0.05; K −1.18; M +0.31.

A change in the value of *V* from 20 km. to 19 km. would reduce the value for the B stars from +1.26 km. to +1.06 km. These quantities must be regarded as very moderate in size.

It appears clear from the Mount Wilson results given in Table III that the variation in velocity with spectral type is very gradual for these distant stars; and except in the case of the M stars, which, because of their number, are of comparatively low weight, the same conclusion may be drawn from Campbell's values after allowance has been made for the effect of the large number of relatively near stars included among his

F, G, and K type spectra. This would be in agreement with the hypothesis of Eddington, already referred to, that the relation between velocity and spectral type might be a relation between velocity and distance, the stars nearest the sun, mainly the types F, G, and K, moving more rapidly than the distant stars. Eddington considered this hypothesis as disproved because an analysis of the A type stars indicated no increase of radial velocity with increasing proper motion. The fact that such an increase exists in the case of the later type stars, however, is shown clearly in Table I. Because of the slight range in proper motion a similar variation for the B and A stars is less certain, although indicated on the face of the results.

The principal feature of interest in this comparison of proper motion and radial velocity is the low average velocity found for the distant stars of types F to M. These stars are on the average stars of high absolute luminosity, and the possibility of a relationship between radial velocity and absolute luminosity has been considered in the communication by Kapteyn and Adams, to which reference has already been made. The observational material included here is much too limited to provide the basis for a discussion of this question. It may be noted, however, that the average radial velocity corrected for the solar motion of such absolutely faint stars as have been observed at Mount Wilson is exceptionally great. The average velocity of sixteen stars with absolute magnitudes below 8 on a scale for which the sun is 5.5 is 36 km. Eight have velocities exceeding 40 km. Since these stars are probably of small mass the evidence so far as it goes is in favor of Halm's hypothesis[5] of the equipartition of energy among the stars, their motions being a function of their masses.

[1] *British Association Report*, 1911.
[2] These PROCEEDINGS, **1**, 14 (1915).
[3] *Lick Obs. Bull.*, No. 196.
[4] *Stellar Movements and the Structure of the Universe*, p. 157.
[5] *London, Mon. Not. R. Ast. Soc.*, **71**, 634 (1911).

LOCALIZATION OF THE HEREDITARY MATERIAL IN THE GERM CELLS

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It has come to be recognized that it must be more than a coincidence that in each animal and plant there are two representatives of each hereditary character (one derived from the mother and one derived from